The National Electric Grid Reliability Test Bed at INL includes a metropolitan-scale energy grid for full-scale testing. It recently helped validate solar storm impacts and the effectiveness of mitigation measures.

Advancing a National Electric Grid Reliability Test Bed

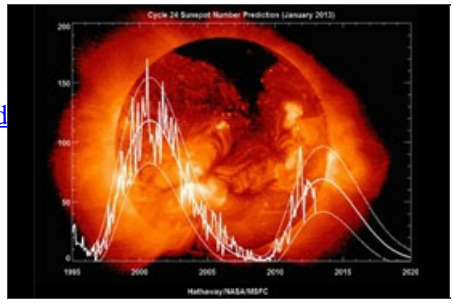
By Keith Arterburn, *INL Communications & Governmental Affairs*

Solar flares and sunspot cycles could disturb or even interrupt power and communications systems for extended periods of time. That has been the concern of many federal agencies, the U.S. Congress and especially the House Homeland Security Subcommittee on Cybersecurity, Infrastructure Protection and Security Technologies.

"This year, 2013, is projected to be a period of maximum activity in the current solar storm cycle," said Dr. Carl Kutsche, who manages Strategic Technology Integration at Idaho National Laboratory. "Although the current solar cycle is predicted to be less intense on average than previous cycles, solar activity spikes that occur during the maximum of any cycle can be significant. These intense spikes have been responsible for disruption and damage to electrical grids in the past, even causing damage to transformers and interrupting grid operations."

Grid-scale testing
During the past decade, many researchers have been modeling and evaluating damage caused by solar storms. Small-scale testing has replicated some but not all of the effects that models have predicted.

Full-scale testing is needed to validate impacts, as well as the effectiveness of mitigation measures, but this level of testing requires an entire metropolitan power grid. No commercial grid can risk this level of testing, as it may impact energy delivery to the nation. The U.S. Department of Energy's INL, however, maintains a metropolitan-scale energy grid for such testing: the National Electric Grid Reliability Test Bed.



NASA's Marshall Spaceflight Center records sunspot activity, which is used to monitor solar storms.

"Recently, INL performed full-scale testing, the first such testing that replicates the exact conditions utility users would experience on the electric grid from solar storms," said INL Power Systems Program Manager Scott McBride. "These tests not only confirmed model predictions of power interruption and equipment damage, they also revealed several other unexpected secondary effects that must be taken into account."

The most interesting results were the high levels of power line harmonics created during a simulated solar event and how these harmonics impacted end-user equipment such as computers and consumer electronics. The nature and levels of the solar-induced harmonics "bridged or penetrated or got through" many power-line filters and caused temporary resets to computer power supplies and disruption to electronic equipment, such as uninterruptible power supplies.

"We have developed an electric grid reliability test bed at INL where full-scale, cost-effective commercially sensitive testing and evaluation can occur safely and securely," said McBride.

INL has conducted applied energy, engineering and testing for more than 60 years. "Here in Idaho, we have a rich testing culture, plus we have full-scale facilities that can be isolated in a controlled testing situation," McBride added. "This is very effective in looking at many conditions to protect national power and communications systems."

Previous experience
NASA and NOAA (the National Oceanic and Atmospheric Administration) have forecast the current Sunspot Cycle 24 — the 24th recorded cycle since 1755 — will reach its peak between December 2012 and December 2013. This sunspot activity spews solar flares (followed by coronal mass ejections) that can create atmospheric disturbances here on Earth.

In March 1989, an exceptionally intense geomagnetic storm caused the shutdown of seven static VAR (volts, amps, reactive) compensators on the La Grande electrical network in Canada, and damaged some high-power transformers. Called the Hydro-Quebec Blackout, a general system

Large scale transformer damage caused by a geomagnetic storm in Quebec, Canada.

failure occurred, impacting all but a few isolated generating substations. More than 9,500 megawatts were lost within seconds, leaving only 430 MW of power in the region and millions of customers without power for several hours.

"The threat and potential damage to power grids from geomagnetic disturbances comes from extra energy being added to a power grid," Kutsche said. "Power lines pick up magnetic solar energy like a giant antenna picking up radio waves. This can cause equipment to operate outside of designed ranges, producing out-of-limit heat, noise, interference and, in some cases, damage."

The most critical power grid failure points — large power transformers — are vulnerable to these solar surges. "Watching a 150,000-pound transformer visibly vibrating and moving along the ground during a simulated solar event (ground-induced current) is a sobering sight," McBride observed during recent tests at INL.

Why Idaho

"Full-scale testing done at INL allows us to understand the failure mechanisms in our most critical national power grid components and to develop mitigations that provide the most effective protection at the least impact to consumers," said Kutsche. "Our electrical grid is an actual, large-scale operational power system featuring the ability to isolate it from other energy consumers, which makes it ideal for this type of testing."

More realistic for a variety of evaluations and demonstrations, the INL Electric Grid Reliability Test Bed also supports validation of computer simulations and helps quantify the interactions with a utility source.

INL researchers inspect two 150,000-pound power transformers prior to a simulated geomagnetic disturbance test.

In addition to the National Electric Grid Reliability Test Bed, INL also hosts the National SCADA (Supervisory Control and Data Acquisition) Cyber Security Test Bed, the Renewable Energy Systems Integration Laboratory and the Hybrid Energy Systems Laboratory. These capabilities form the core of a network reaching multiple Department of Energy, university and commercial laboratories. It provides an unmatched virtual research, test and evaluation network.

Test Bed Specs

The National Electric Grid Reliability Test Bed at INL allows customers to access a utility-scale 138 kV transmission system and 13.8 kV overhead and underground distribution systems that can be customized for multiple power grid configurations. For testing purposes, portions of the grid can be isolated for conducting scalable performance, equipment and system-type testing.

The 50 MW electrical power transmission and distribution grid was designed and built within INL's 890-square-mile desert site. The loop-fed substations are linked with state-of-the-art SCADA and dedicated fiber-optic communications.

All transmission-level over-current relaying is done using the latest differential line relays in a long/short side-trip scheme configuration. This protection scheme supports isolation of individual loop segments between the substations in the event of a fault, which provides a high degree of electric power availability to all research complexes on the loop, 24/7, under all weather conditions.

This power grid test bed is used specifically to support INL's National and Homeland Security missions, including electric power transmission and distribution research, SCADA, wireless communications and physical security missions.

Feature Archive